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**TRAINING AND JOB AIDING CONSIDERATIONS
FOR THE INTEGRATED MAINTENANCE
INFORMATION SYSTEM**

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SUMMARY

The Air Force Human Resources Laboratory (AFHRL) is conducting research and development (R&D) of an Integrated Maintenance Information System (IMIS). IMIS will demonstrate the capability to access and integrate information from multiple sources and present the information to technicians through a rugged, hand-held computer. Results of the program will form the basis of requirement specifications for such a system.

AFHRL is researching many areas key to the success of the IMIS concept. These areas include digital authoring and presentation of maintenance instructions, integrated diagnostics aiding, human-computer interaction, advanced portable computer hardware technologies, and potential training applications. IMIS will be the culmination of a complex and thorough R&D effort. Specifications developed by the project will be validated through field tests performed by Air Force maintenance technicians. As a result, IMIS will improve the capabilities of maintenance organizations to effectively utilize available manpower and resources to meet combat sortie generation requirements.

In work previously accomplished by AFHRL, representative base-level maintenance training requirements were identified. Based on these requirements, a series of "operational scenarios" were developed to help conceptualize how IMIS technology might be used to support base-level maintenance training. It appeared that IMIS could improve upon present methods used to provide this training.

In the work reported here, a demonstration was developed to assess the feasibility of using the IMIS Maintenance Diagnostic Aiding System (MDAS) to meet selected training requirements noted in the "operational scenarios." Additionally, other significant developments surrounding the maintenance training environment, such as the Core Automated Maintenance System (CAMS), were surveyed.

Based on the work accomplished and the positive feedback from Tactical Air Command maintenance and training personnel, this IMIS training module could support many forms of useful training ranging from basic familiarization to detailed repair. The IMIS training module's potential appears unlimited. Additional effort should be expended to further develop and expand its capabilities.

PREFACE

The purpose of the present effort was to evaluate the feasibility of using the data base from the diagnostic module of the Integrated Maintenance Information System (IMIS) for training purposes. In particular, the study examined the feasibility of using the IMIS Diagnostic Module as the basis for a simulation to teach troubleshooting techniques to maintenance technicians. This effort was conducted under Contract Number F33615-85-C-0010 by Systems Exploration, Incorporated (SEI), for the Air Force Human Resources Laboratory, Logistics and Human Factors Division, Combat Logistics Branch (AFHRL/LRC). The AFHRL/LRC project manager was Captain Gail M. McCarty.

The research for this task was performed by the Dayton regional office of SEI. The principal investigator was Anthony S. Babiarz, assisted by Johnnie H. Jernigan and Colleen K. Gumienny. Additional work, under subcontract to SEI, was performed by Guy N. Fauchaux of Advanced Technology, Incorporated (ATI), Reston, Virginia. ATI provided input on training requirements, training developments, and aided in prioritizing the training requirements identified in the training scenarios.

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TRAINING AND JOB AIDING CONSIDERATIONS FOR THE INTEGRATED MAINTENANCE INFORMATION SYSTEM

I. INTRODUCTION

The Air Force Human Resources Laboratory (AFHRL) is conducting a research program to develop a proof-of-concept Integrated Maintenance Information System (IMIS). The proof-of-concept IMIS will demonstrate the capability to access and integrate large quantities of information through a ruggedized, hand-held computer. The IMIS will provide maintenance technicians with easy access to all maintenance information required to do their job. It will provide them with technical order (TO) data, diagnostic data, various types of maintenance management information (including historical records, maintenance schedules, job assignments), and supply information (availability, status, etc.). In addition, it will provide automated tools for maintenance data collection and reporting, ordering supplies and materials, and providing training for maintenance personnel in system knowledge, maintenance procedures, and ancillary training (safety, security, etc.). The effort described in this paper studied the potential of and requirements for the IMIS as a tool for presenting training in system knowledge and troubleshooting techniques.

Background

A major goal of the AFHRL is to develop tools and techniques to help Air Force maintenance organizations more effectively accomplish their mission. An area of special interest is the development of techniques to take maximum advantage of new technologies now being applied to maintenance operations and to minimize new problems created by these technologies. The development of inexpensive data automation techniques has made it possible to automate a number of maintenance support functions. The automation of these functions has the potential to significantly improve maintenance operations. However, the development of separate automated systems for different maintenance functions such as maintenance management, technical data, and supply has created new problems by requiring the technician to learn to use several different systems which have different hardware, data access procedures, and human/computer interface techniques. In addition, it has caused a proliferation of equipment in the maintenance shops, with the result that several different types of computer hardware are required in each shop. This results in increased costs for acquiring and maintaining the equipment and uses large amounts of bench and floor space in the shops. To overcome this problem, a single computer system is needed which is capable of interfacing with all of the maintenance data bases and accessing data from any of the data bases by using a common set of user protocols. The objective of the IMIS program is to develop such a system.

The IMIS will provide the technician with a means of accessing any of the maintenance data bases. It will use common hardware and data access techniques to provide the technician with the capability to retrieve any information needed from any of the data bases. The system will make it possible for the technician to access any data base without having specialized knowledge of the data base. Accessing the different data bases will be "transparent" to technicians in the sense that they will not know which data source or base the information is coming from. From their point of view, there will be only one system, the IMIS.

Under the IMIS program, a proof-of-concept system will be built and tested. The IMIS will provide a common interface with existing, under development, and planned maintenance information systems. In addition, it will interface directly with aircraft systems to provide an interactive diagnostic capability. System design will be flexible to provide for interfacing with new information systems that may become available at a later time. The initial proof-of-concept will interface with the Core Automated Maintenance System (CAMS), the Air Force Technical Order Management System (AFTOMS), the Centralized Engine Maintenance System (CEMS), and the

Standard Base Supply System (SBSS). Where no automated system is available or expected to be available in the near future, the capability for a function such as training will be developed and incorporated into the IMIS for test purposes. (See Link, Von Holle, and Mason, 1987 for a complete description of the IMIS system.)

The IMIS proof-of-concept will be evaluated in field tests conducted in an operational environment. The proof-of-concept system specifications will incorporate the results of the field test. The revised specifications will then be used to establish the requirements for the development of an IMIS for an operational Air Force weapon system.

The IMIS will be the culmination of a complex and thorough research and development (R&D) effort. AFHRL is performing R&D in many areas relevant to the IMIS. These include authoring and presenting maintenance instructions, integrated diagnostics aiding, human-computer interaction, evaluation of advanced portable computer hardware technologies, and examination of potential training applications for the IMIS. The present effort examined one potential application of the IMIS as a training aid.

In work previously accomplished by AFHRL (Brandt, Jernigan, & Dierker, 1987), representative base-level maintenance training requirements were identified. Based on these requirements, a series of "operational scenarios" were developed to conceptualize how IMIS might be used to support base-level maintenance training. One of the training applications identified in the study was the use of the IMIS diagnostic subsystem, the Maintenance Diagnostic Aiding System (MDAS). In the present effort, concepts for using the MDAS as a basis for providing training in system knowledge and troubleshooting techniques were further developed, and a demonstration assessed the feasibility of the approach.

Objective

The primary objective of this effort was to examine and demonstrate the feasibility of using MDAS, the IMIS diagnostic module, for presenting troubleshooting training. The major effort centered around two IMIS training requirements: (a) use of a combined technical data base developed for training and job aiding; and (b) identification of the most likely candidate areas in maintenance to which to apply a training simulation using the portable computer.

II. APPROACH

To demonstrate the feasibility of using the MDAS to present diagnostic training, Systems Exploration, Incorporated (SEI) identified types of information to be trained and the capabilities of the MDAS to present the information. A strategy was developed to design a system capable of simulating the use of MDAS to present training. The training materials needed to adequately demonstrate the system were also developed.

Requirements Analysis

To identify the types of information to be trained, previous IMIS training, human interface and diagnostics studies, and the current Air Force training policies and requirements were reviewed. In addition, base-level training personnel were contacted to describe the types of information they provided at base level. Specific training requirements and technical data from the selected testbed system, the F-16 Stores Management System (SMS), were also reviewed. SEI was assisted by Advanced Technology, Inc. (ATI) in identifying the training requirements. Opportunities to recognize and incorporate training technology improvements and field-generated requirements were actively sought.

MDAS Review

Since the MDAS was to constitute a major element of the training, the capabilities of MDAS were carefully analyzed to identify ways it could be used for training. The MDAS and its training potential are briefly described below.

MDAS Description

The MDAS was developed by AFHRL as a primary element of the IMIS. The MDAS is an automated diagnostic capability providing the technician with the most efficient diagnostic routine to correct an observed system fault in the minimum time. A unique characteristic of MDAS is that its algorithms minimize the time to repair an aircraft or component part, not merely the time to isolate a fault.

The basic task of MDAS is to assist the maintenance technician in isolating and repairing a fault which exhibits a symptom of improper behavior. MDAS evaluates known symptoms and system status parameters and recommends a sequence of tests or checks to the technician to most efficiently locate the fault. The system uses test results input by the technician and directly interrogates aircraft systems for built-in-test (BIT) information. Each test or check is based upon the results of the previous test or check. In addition to providing diagnostics information, the MDAS is interfaced with the technical data system. Procedural technical data are called up as needed to provide the technician with instructions on how to perform a required test or rectification.

The MDAS closely models how equipment behaves under failure and recommends the "best" test or repair action to rapidly isolate and repair the fault. The technician has the option of selecting the recommended action or an alternate action (identified and prioritized by MDAS). "Best," in the case of MDAS, describes the option which has the highest probability of efficiently isolating the fault and leading to the rectification of the failed component or components. The MDAS runs on a portable computer which is capable of connecting to the aircraft's MIL-STD-1553 data bus. The data bus directly interrogates the aircraft's systems to acquire BIT information for use with the MDAS diagnostic algorithms.

In determining test recommendations, MDAS uses a variety of information from the MDAS data base, information input by the technician, and data extracted directly from the aircraft's system via the data bus. Data from the MDAS data base includes information on the fault mean time between failures (MTBF), component reliability (probability of failure), system historical records, system/fault relationships, test spans, test times, and repair times. Information input by the technician includes observed symptoms, test results, and logistics and operational constraints. Information received from the aircraft's data bus includes inflight self-test results generated by the aircraft and BIT results from tests initiated by MDAS.

MDAS also provides a look-ahead subroutine to allow temporary examination of a specific action and its effect on the plausible set of faults (those potential faults which could have caused the symptom or fault code). The look-ahead function allows the user to temporarily advance the present plausible set of faults to examine the potential result without actually performing the test or action. The user input of a pass or fail of the related action will result in a display of the effects on the plausible set of faults. The user can then return to the point at which the look-ahead subroutine was entered and perform an action with some foresight. A conceptual flow diagram depicting the basic operations of MDAS is shown in Figure 1.

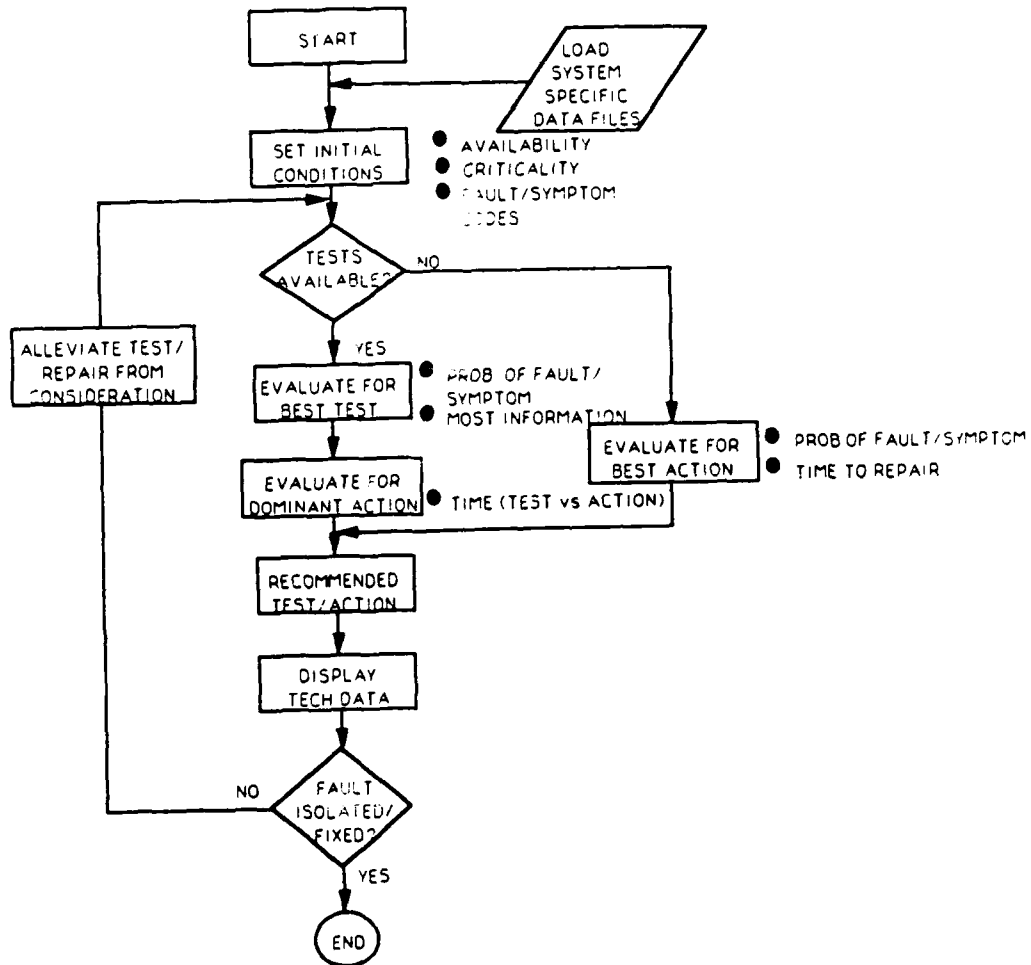


Figure 1. Basic Operation of MDAS.

The foundations of the MDAS are the attributes of the faults, symptoms, tests, and rectifications modeled as dependent associations. The symptoms observed by the aircrew and/or the maintenance technician are compared with the modeled association to identify and select an initial set of suspected faults. After this initialization is complete, MDAS determines if any diagnostic tests are available and rank orders those determined relevant. The tests are ranked based upon their capability to split the initial set of plausible faults. MDAS chooses tests such that the probability of failure of the chosen components is approximately equal to the probability of failure of the components not chosen. This probability is based on fault MTBF. The best test is the one which produces the split closest to equal and has the least time cost associated with accomplishment of the test procedure.

The best test is then compared to the potential dominant action, the action whose likelihood of success is so great that it is recommended prior to other available tests that would reduce the plausible set. It is the repair action which has the highest probability of repairing or removing the fault and has the least time cost. The resultant ranking of all available tests and the dominant action, if present, are then presented to the technician.

The task test selected and performed by the technician or MDAS routine is used to modify the plausible set of faults, and the sequence is repeated. If no useful test remains and an ambiguity still exists as to the fault location, then MDAS evaluates all remaining actions (based upon the fault probabilities each contains and the time to accomplish) and presents this ranking to the technician. This process is repeated as the technician inputs the results of his or her choice until the fault is repaired or removed from the aircraft and the system successfully passes its functional checkout. The fault information and test sequence results can accompany the faulty line replaceable unit (LRU) to the next level of repair for historical and statistical purposes.

Training Capabilities

One of the main features of the MDAS which gives it potential as a training aid is its look-ahead capability. The MDAS look-ahead capability allows technicians to follow a possible diagnostic sequence through completion without actually performing the tests. This feature allows them to preview possible actions and evaluate the probable results in view of the immediate situation (e.g., time constraints) before going through the diagnostic process. It also allows them to evaluate their own "hunches" as to the possible cause of the fault and learn more about how the system works.

In addition, the MDAS provides the capability to include at any point links to other data bases. Thus, it is possible to directly link the MDAS to a training data base. This makes it possible for the technician to seek explanatory or training information at any point in the diagnostic procedure. For example, if, in the process of performing a diagnostic routine, information is needed on the function of a component, the technician can request the information. The MDAS human/computer interface provides simple procedures for rapid retrieval of the information. The capability to access training information could be used in two ways. In a pure "training implementation," the technicians would use a "training version" of MDAS to complete a series of troubleshooting exercises. In this case, the MDAS training system would provide hypothetical test results to control the troubleshooting sequence. The technicians could be provided or allowed to access explanation for each action recommended by MDAS as they proceed through the exercise. In addition, they could be provided or allowed to access system information on the components of the system and component interrelationships. In an "operational implementation," the technicians would be able to call up training information as they work on an actual problem. The training information would provide an answer to a question or allow technicians to better understand some feature of the system on which they are working or why the MDAS recommended a particular

action. Based upon the results of this analysis, it was determined that the MDAS training demonstration system would consist of two unique modules, a "what-if" module and a simulation module.

IMIS/MDAS Training Demonstration Development

Modification of the MDAS software to develop a fully functional training system was beyond the scope of this effort. Thus, it was necessary to develop a simulation of an IMIS/MDAS training system to demonstrate the feasibility and features of such a system. Due to cost considerations, development of the simulation would necessarily have to be based upon existing off-the-shelf software. A review of the available software packages indicated that the Hypercard software, which operates on the Macintosh computer, was the most suitable software available within cost constraints.

The Hypercard software provides a capability to rapidly create screens of information (including both text and graphics) and link them together so that the user can rapidly move from one screen to another in a sequence specified by the author or by the user (within constraints established by the author). This capability made it possible to develop a simulation of MDAS diagnostic routines for representative troubleshooting problems. The simulation used diagnostic sequences for the F-16A SMS that were generated using the MDAS. The sequences were developed by assuming that the given fault existed and running the MDAS to identify the sequence of troubleshooting actions recommended by the MDAS. Hypercard screens were generated for each recommended action. The MDAS information was formatted on the Hypercard screens using the same format as used by MDAS to present instructions. The resulting Hypercard presentation resembled the MDAS presentation. After the basic sequence had been determined, an analysis was made of each action to determine what additional training information would be needed to support each screen. For example, if a screen instructed the technician to test the function of a component, a screen describing the function would be developed and linked to that screen so that the technician could call up that information if desired.

The training demonstration closely resembles the baseline version of MDAS as far as the visual screens are concerned. However, some of the features of MDAS such as pan, critical modes, supply availability, and suspend were not included, as they would not contribute significantly to the training capability. Other functions such as look ahead, back up, tell more, symptoms, and fault codes were included because of the training opportunities they provide.

Sample Data Development

Sample Diagnostic Sequences. Sample diagnostic sequences for the SMS were developed using the MDAS algorithms running on a Sun workstation. Diagnostic data for the SMS had been developed previously for another MDAS test. The sequences were developed by assuming that a given component was faulty and then having MDAS compute the diagnostic sequence that would lead to the isolation of that fault. The results that would occur at each available test point were identified so that the proper test result could be displayed if the trainee selected that test as he or she progressed through the training. This information provided the basis for the diagnostic portion of the demonstration data base. In addition to the diagnostic sequences, the diagnostic data base provides failure rates, symptom-fault associations, task times, test spans, and the sequence of operational checkouts. This information is used by the diagnostic routine to sequence options along with the appropriate graphics, and it is normally hidden from the user. However, for the IMIS/MDAS training simulation, this information is presented to the trainee in a readily understandable format.

Sample Technical Data. The MDAS identifies the tests and rectifications to be made. However, the MDAS data base does not contain instructions for conducting the tests or making the rectifications. Since the technician must have instructions for these tasks, MDAS contains references ("hooks") to the automated technical data system. When the instructions are needed, the MDAS automatically calls the instructions from the technical data system. Because an automated technical data system was not available for the SMS, it was necessary to create some sample technical data for use in the training demonstration. A small amount of data was developed using the F-16 SMS Job Guide Manuals as the data source. Only data sufficient to demonstrate the concept were developed, and the basic procedures were provided without graphics.

The TO data base provides training information such as theory of operation or function of components. Other TO data in the data base that are available for use in training (but not incorporated in the demonstration system) include supply identification, to include TO, figure, and index for part ordering purposes; Maintenance Data Collection (MDC) documentation codes with the added feature of developing an automated AFTO FORM 349, MDC Form; safety information; and required input conditions.

Sample Training/Instructor Data. Training materials were developed to supplement the MDAS and technical data. The data were intended to substitute for an instructor and to provide the types of supplemental information that an instructor would provide or that would be obtained from a reference manual. The instructor data base includes the enhanced explanations and personal experiences normally passed on to the trainee by the trainer or instructor. It also includes training materials designed to cause the trainee to think through the problem (such as choosing the most efficient option from a list of options, followed by an explanation of the correct answer). Training evaluation questions were provided at the end of the simulation routines but not for the what-if routines.

III. IMIS TRAINING DEMONSTRATION DESCRIPTION

A proof-of-concept training demonstration system was developed which can be used to demonstrate the viability of adapting the MDAS for training purposes. As indicated above, the module is based on the MDAS diagnostic structure and off-the-shelf simulation software (Hypercard). The demonstration is operated using representative diagnostic sequences developed using MDAS, representative technical data (procedures, etc.) similar to those IMIS will provide from an automated technical order system in support of MDAS, and training and explanatory materials required to supplement MDAS in presenting training. The demonstration system is briefly described below.

Tutorial

A short tutorial is provided at the beginning of the training session. It is used to explain the basic information needed to operate the demonstration system. The tutorial includes:

1. A sample initial screen displaying the usable function keys used to navigate through the routine (Figure 2a.). The display presents an information screen with a block diagram similar to those used in MDAS to illustrate the relationships between components. The functions shown in blocks at the bottom of the screen are used to move within the demonstration. Functions are selected by using the mouse to move the arrow to the desired function block and clicking the mouse. (Note: The functions shown for the training module may or may not be the same as those used in the actual MDAS, depending upon the information available; nor were all the functions activated for this demonstration.)

2. A legend of the graphics (Figure 2b) providing definitions of the graphic coding used on the MDAS block diagrams (as shown in Figure 2a).

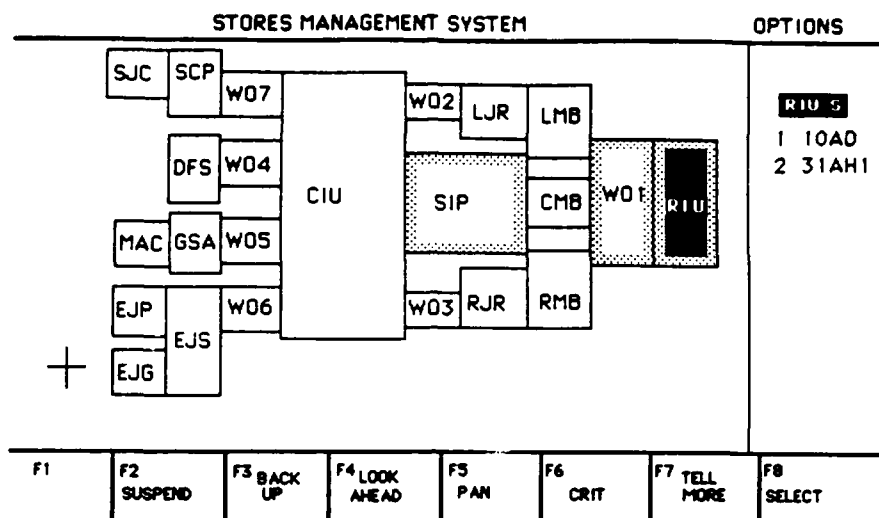


Figure 2a. Sample Screen. This is an example of a sample screen. It includes the function keys, F-1 - F-8, which are used to maneuver through the diagnostic/training module screens. A definition of each key may be accessed by clicking on the desired function key.

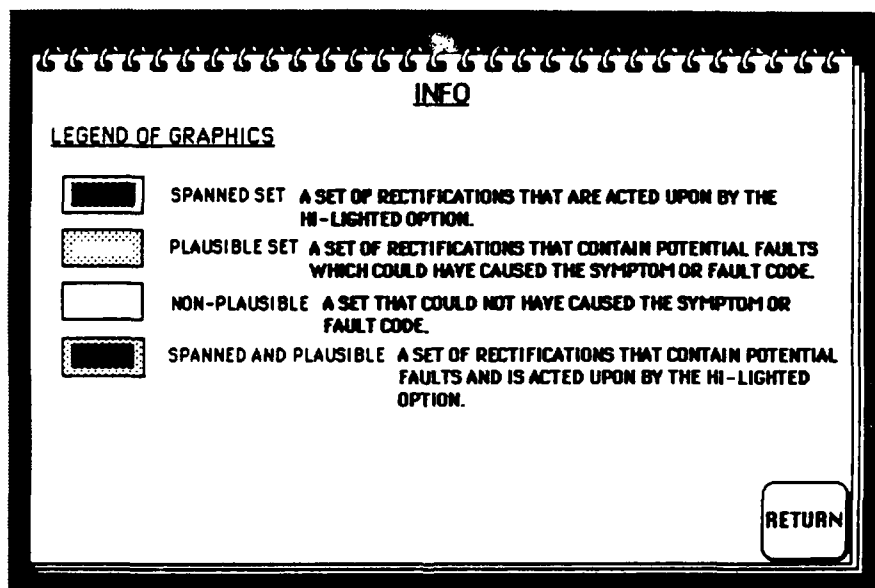


Figure 2b. Diagram Information. This screen contains a legend with explanation of the graphics found on the SMS screens.

3. An example of a display illustrating how additional information can be retrieved (Figure 2c). The example illustrates how the user can obtain additional information on any component on the block diagram by moving the arrow to the block representing the component on the block diagram.

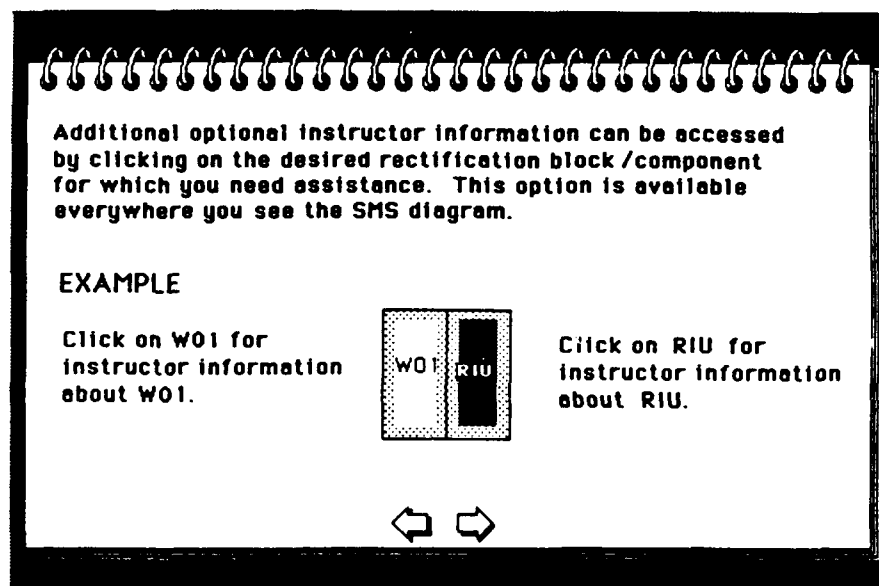


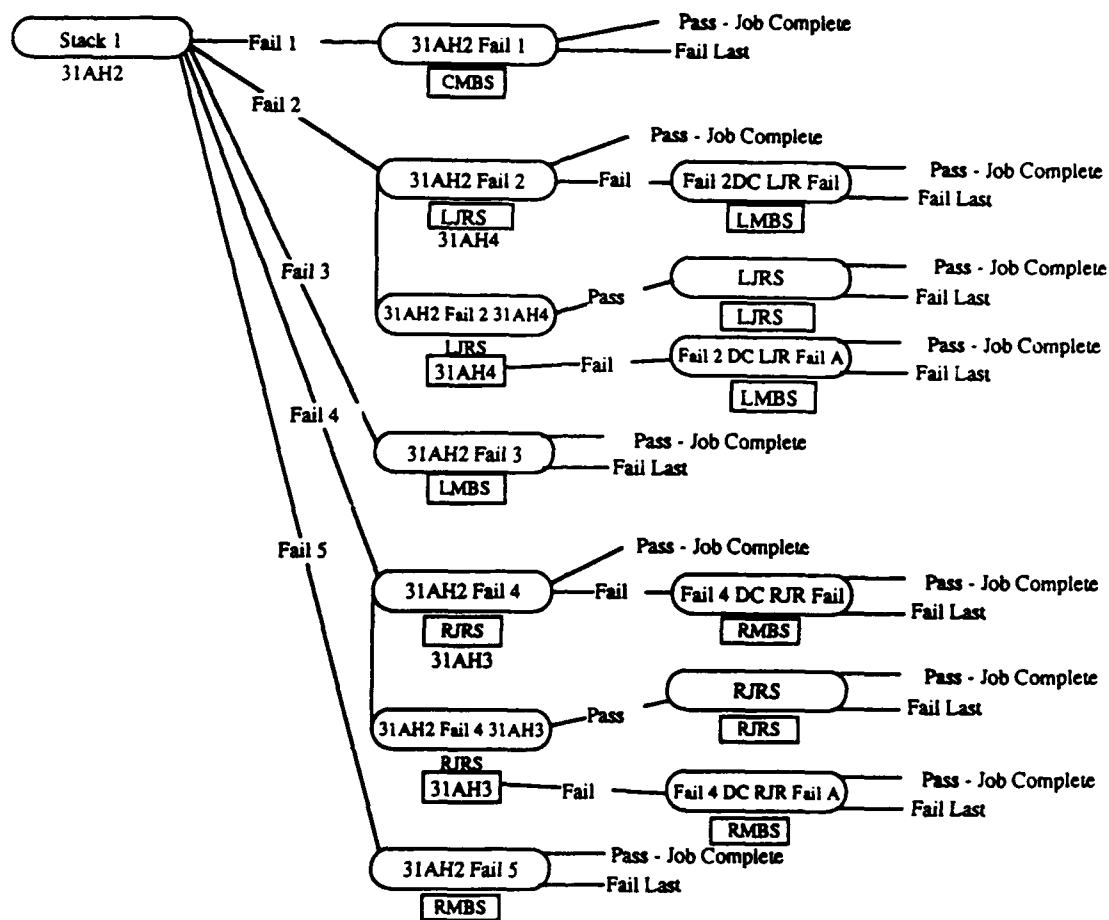
Figure 2c. Operational Data. Additional information is available by clicking on the desired block/ component.

Training Data Structure

For demonstration purposes, two training modules were developed: a what-if module and a simulation module. The what-if module allowed the technician to examine the consequences of any given decision. The simulation module allowed the technician to follow the isolation of a fault using the MDAS sequence. Opportunities were provided to seek additional information as the diagnostic process continued. The modules shared common data elements where there was overlap; however, they differed as to the manner in which the technician was allowed to move about in the module.

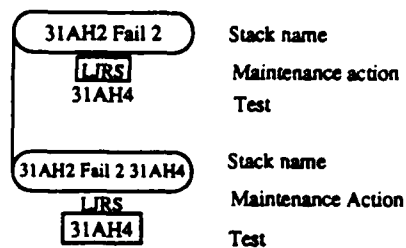
What-If Module

The what-if structure developed in the preliminary design consisted of a graphic representation of the exhaustive look-ahead tree associated with symptom 9410AD of the F-16A SMS (as defined in the F-16 SMS Fault Isolation Manual). This look-ahead tree provides an analysis by which consequences from the diagnostic actions can be examined. This symptom was one of four symptoms installed into the baseline diagnostic routine and was chosen to demonstrate the training potential of the diagnostic data base. The selection of this symptom was based upon the size of its exhaustive look-ahead tree and the variety of available situations, such as multiple outcome tests and dominant actions. Figure 3 represents 20% of the look-ahead tree for symptom 9410AD and illustrates how extensive this tree is. This tree was prototyped as a hard-wired versus active tree.



WHAT - IF MODULE

Vertical line indicates stacks linked by option selection instead of option results



Fail. Last - indicates all plausible actions have been eliminated without resolution of the problem

Pass-Job Complete - indicates passed functional check for rectification

Figure 3. Training Module Skeleton - What-If.

In Figure 3, a horizontal line indicates the linkage between the stacks due to the resultant actions. The stack names are included in the ovals, with the options currently available listed below the stack names (ovals). The option in the rectangle denotes the selected option within that stack.

Simulation Module

A second skeleton (Figure 4) was developed and used in the development of the simulation module. The two skeletons differ in their ability to traverse branches within the tree. The what-if module allows traversing all possible branches, whereas the simulation module will lead the trainee down a predetermined path. This latter path is denoted by a heavy border around the stack name, as shown in Figure 4, and is established by fault simulation.

Using the IMIS/MDAS Training Demonstration

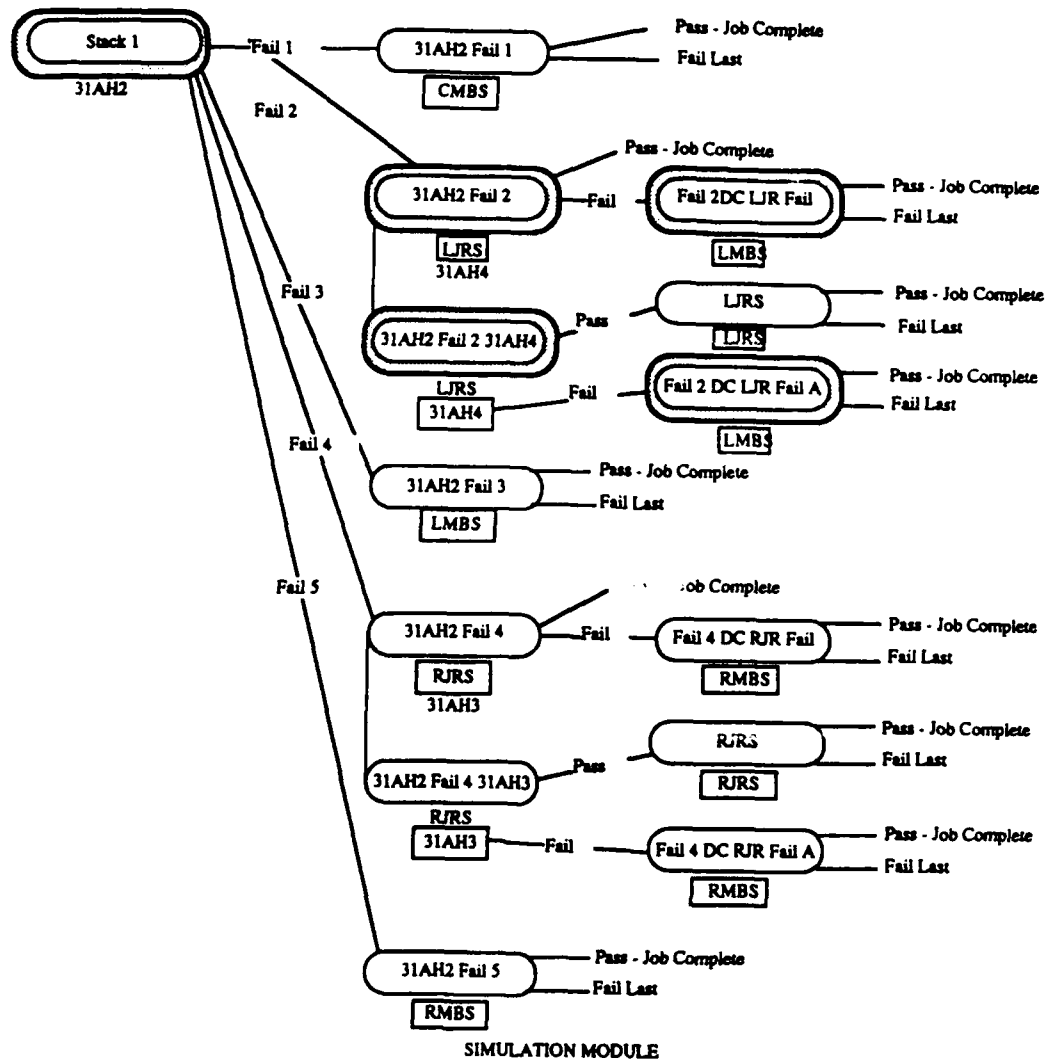
The training system is designed for use either independently by the technician or under the supervision of a trainer/instructor who may select the mode of instruction or select the problem to be used. After activating the system, the technician is first given a short tutorial which explains the use of the system (how to select the next screen, meaning of coding used, etc.), the two modules of instruction, and the instructor feature. The capabilities of the instructor feature, what-if module, and simulation module are briefly described below.

Instructor Capability

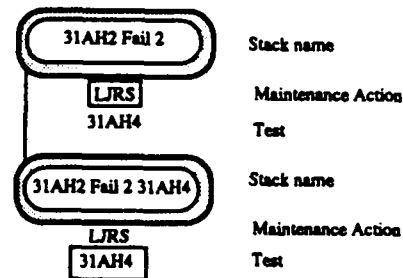
The data in the instructor data base provide the technician with supplemental information such as an instructor would provide. It is there to provide information that the technician would ask an instructor or to ask the technician questions that an instructor might ask. For instance, once the technician selects a particular training module, a screen containing a list of symptoms or fault codes associated with that particular subsystem appears on the screen. If the technician wants more information on the symptom or fault code, he or she can call up an instructor assist screen, which provides a brief explanation of the symptoms or fault codes themselves. If desired, a second-level expert instructor assist, developed from the diagnostic data base, can provide an in-depth explanation of the symptom or fault code selected. This explanation is depicted as a rank-ordered list of all rectifications in the plausible set associated with the symptom and any test which spans the rectification. Another set of information about the symptom is displayed as a rank-ordered list of tests which will assist in the diagnostics, time to accomplish the task, and percentage of pass/fail for each task. (See Figures 5a, 5b, and 5c for example instructor screens.)

What-If Module

In the what-if module, the instructor or student has the ability to examine any of the symptom, fault, test, and rectification codes to determine the various outcomes of the selections among the diagnostic alternatives. Given a particular symptom or fault code, the technician can proceed through the diagnostic troubleshooting process (without actually performing any hands-on maintenance) to examine the effect of a particular option choice. The what-if module provides the ability to familiarize and expose a trainee to the diagnostics of a new system or subsystem.



Vertical line indicates
stacks linked by option
selection instead of option
results



Fail Last - indicates all plausible actions have been eliminated without resolution
of the problem

Pass-Job Complete - indicates passed functional check for rectification

Figure 4. Simulation Module Skeleton - Simulation.

INSTRUCTOR
(SYMPTOMS)

1. 9410AD FAILED MFL NUMBER SMS 001 THROUGH 009
(INDICATES LOST COMMUNICATION WITH THE PYLONS)
2. 9410AE FAILED MFL NUMBER SMS 010
(INDICATES LOST COMMUNICATION WITH LEFT WING)
3. 9410AF FAILED MFL NUMBER SMS 012
(INDICATES LOST COMMUNICATION WITH RIGHT WING)
4. 9410AG FAILED MFL NUMBER SMS 013
NOT COINCIDENT TO USING A KNOWN SWITCH
(LOST COMMUNICATION WITH COCKPIT SWITCHES AND CIU)

RETURN TO SYMPTOM

Figure 5a. Level 1 Instructor. The Level 1 Instructor provides a brief explanation of the symptoms associated with the particular subsystem and/or subsystems.

IN-DEPTH EXPLANATION FOR SYMPTOM # 1 Page 1

Symptom 9410AD plausible set contains the following:

Ranking	Rectification	Spanned by test
1	CIU	---
2	RIU	10AD
3	WD1	---
4	SIP	31AH1
6 (tie)	LJR	31AH2
6 (tie)	RJR	31AH2
8 (tie)	LMB	31AH2, 31AH4
8 (tie)	RMB	31AH2, 31AH4
9	CMB	31AH2

Continue on page 2.

➡

Figure 5b. Level 2 Instructor. The Level 2 Instructor gives an in-depth explanation of each symptom. It includes a ranking of all plausible rectifications and lists the tests which span each rectification. The only button on the screen will allow the user to continue on to the Level 2, page 2, instructor or additional information.


IN-DEPTH EXPLANATION FOR SYMPTOM #1					Page 2
The initial ranking of options contains only the following tests (no dominant component).					
Ranking	Option	Time	# of outputs	% of Pass/Fail (s)	
1	31AH2	30	6 (MTO)	60/6/13/2/13/2	
2	31AH3	30	2	97/2	
3	31AH4	30	2	97/2	
4	10AD	50	2	93/6	
5	31AH1	30	2	99/0	
<div>  <div>EXIT EXPERT INSTRUCTOR</div> </div>					

Figure 5c. Level 2 Instructor. The Level 2 Instructor provides information such as ranking, time to accomplish, number of outputs, and the percent of times this option will pass/fail. The button in the left-hand corner allows the user to Page Back and review the Level 2 Instructor on page 1.

The training information available for each rectification block is derived from three distinct data bases: the technical order data base, the instructor data base, and the diagnostic data base. The theory of operation or function of each rectification block may come from the technical order data base and can be enhanced by the instructor data base. Information such as time to accomplish a task, plausibility/non-plausibility within the given set, a test which spans the faults within the rectification, and the probability of pass/fail is obtained from the diagnostic data base at varying levels of proficiency.

Simulation Module

The simulation module uses the rudimentary MDAS training function as its baseline. The student can choose between random, frequent, rare, and instructor-chosen faults. For this demonstration, only the frequent and rare faults are used. One rare fault path, portraying an infrequently occurring malfunction, and one frequent fault path, portraying a commonly occurring malfunction, were developed. Contained in the frequent fault path (Figure 6a) is a sample initial screen for that particular option, Central Interface Unit Swap (CIUS). Following a presentation of the applicable technical data, through the SMS confidence operational checkout, the user would find that the CIUS passed the SMS confidence operational checkout (Figure 6b). This frequent fault path option guides the user through the required steps in an effort to develop the proper diagnostic techniques and reasoning skills. This mode of operation is consistent throughout the simulation module where fault insertion causes the correct diagnostic path to be established among the options.

Contained in the rare fault path (Figure 7a) is a sample screen for option 31AH2. The next screen (Figure 7b) provides the required test information with a simulated indication of test results.

It is now up to the user to choose the proper outcome based on the information provided (Figure 7c). Following this path, the user is required to apply proper thought, reasoning, and experience to rationalize the proper solution.

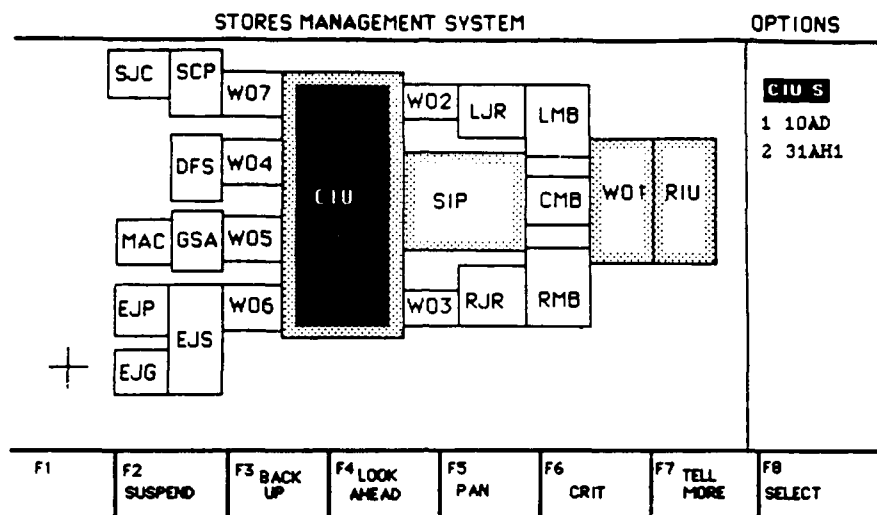


Figure 6a. Frequent Fault Path. This screen is the result of passing 31AH2. It has a full complement of information available to the user. The user has the capability to choose any option at this point.

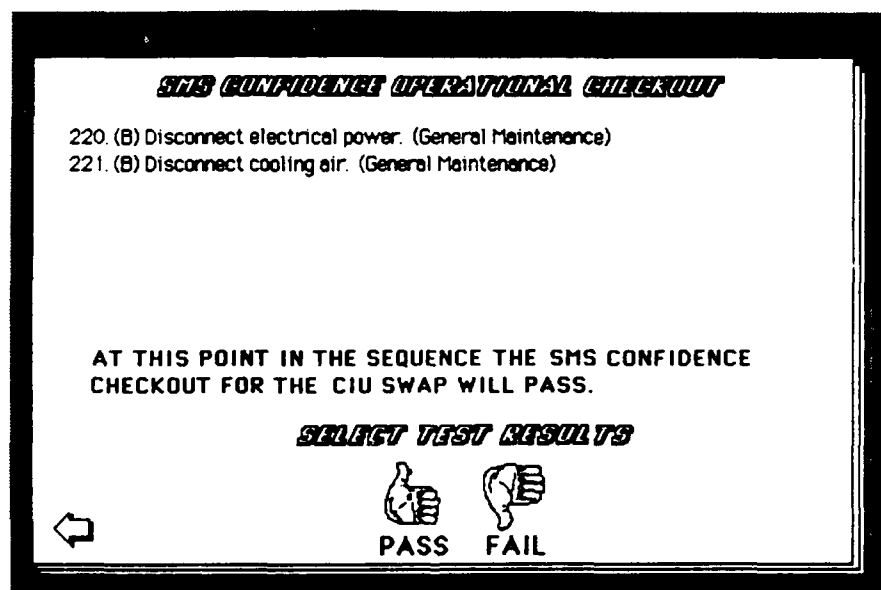


Figure 6b. Operational Checkout. If the CIU is selected from the option screen, the user would be presented with technical data as in the what-if routine. This confidence operational checkout result screen indicates this checkout passed.

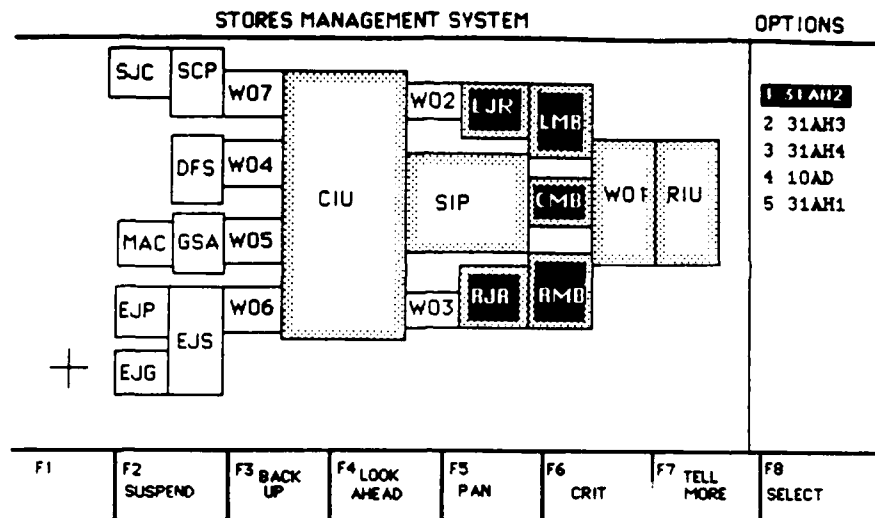


Figure 7a. Rare Fault Path. This screen shows the initial options screen for the rare fault sequence. The same type of information is available for each rectification block and each function.

31AH2 TEST INFO PAGE 2

1. Disconnect 9411P122 and 9411P123 from CIU
2. Verify Resistance

Left Wing- 9411P122/P123 pin 46 to pin 47	49	50
Right Wing	26	44
	31	52
Centerline	45	27
	51	30

All pins to Ground should read open. Resistance for Right or Left wing should be from 22.5 to 27.5 ohms. Centerline should be from 40.5 to 49.5 ohms.

SIMULATED INDICATIONS: LEFT WING READS 0 OHMS TO GROUND ON ALL FOUR PINS.

INSTRUCTOR

←
→

RETURN

Figure 7b. Test Information. This screen resembles the frequent simulation path test procedures screen. The difference is in how results are presented. Test results were previously indicated as Pass/Fail; here, simulation indications are furnished and the user selects the result. Selecting the Instructor button provides additional information. Other buttons include Page Back/Page Forward arrows and Return to the options screen.

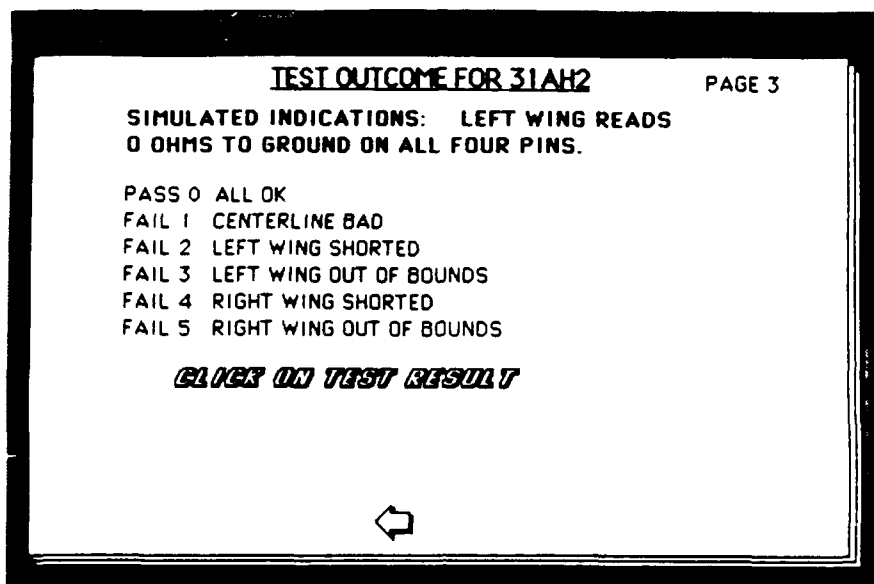


Figure 7c. Results Selection. This screen redisplayes simulated indications along with potential outcomes. The user must evaluate the output for the applicable simulated indication and activate the appropriate results. The Previous Page arrow allows the user to reexamine the procedures.

Upon selecting the results of the test, an intermediate instructor screen (Figure 8a) presents three possible options, with limited information for the next plausible set. It is up to the trainee to select which one of the three would be the next most efficient option to perform. The selection of an inefficient option will result in an inefficient option instruction screen (Figure 8b) to explain why this choice is inefficient. The trainee is returned to the previous intermediate instructor screen (Figure 8a). Upon selection of the most efficient option, an efficient option instructor screen will appear (Figure 8c). This screen explains why this option is most efficient and will allow the trainee to continue to the resultant plausible set.

IV. DISCUSSION

Although the IMIS/MDAS training demonstration system was not formally evaluated, this effort has clearly shown that the development of such a system is feasible. The system was informally demonstrated to approximately 20 maintenance technicians and field training detachment (FTD) instructors at MacDill AFB, Florida, in May 1988. Reactions from these personnel were very positive. All of the technicians who saw the demonstration and had an opportunity to try it indicated that they thought it would be useful. The FTD instructors were particularly impressed with the system's potential for teaching troubleshooting techniques to technicians. They encouraged its further development and implementation. In addition to the demonstrations to personnel at MacDill AFB, the system has been demonstrated to a variety of Air Force, Department of Defense (DOD), and contractor personnel working in the areas of training, computer-aided acquisition, and logistics. Again, positive reactions were obtained.

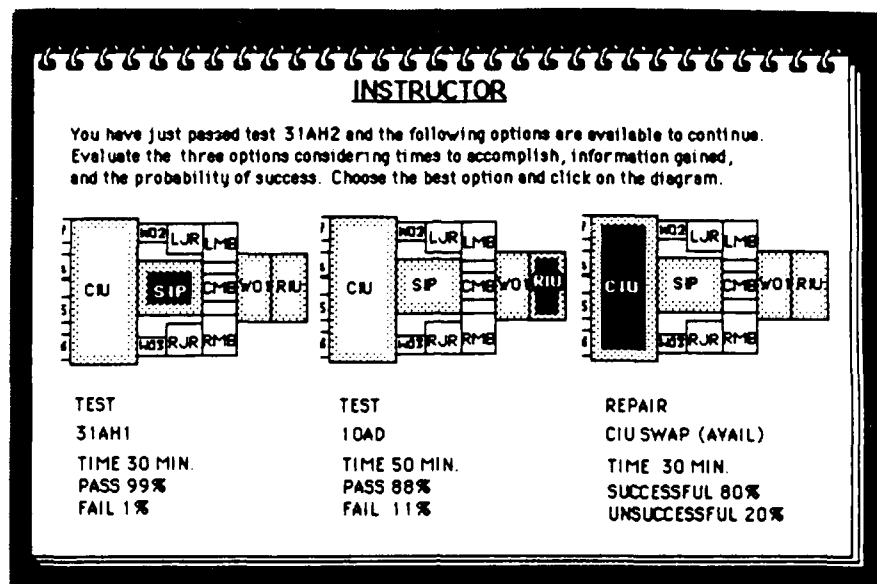


Figure 8a. Initial Options. At this screen the user is shown three options for the next plausible set in the sequence. The user must analyze the information and select the most efficient option in order to continue.

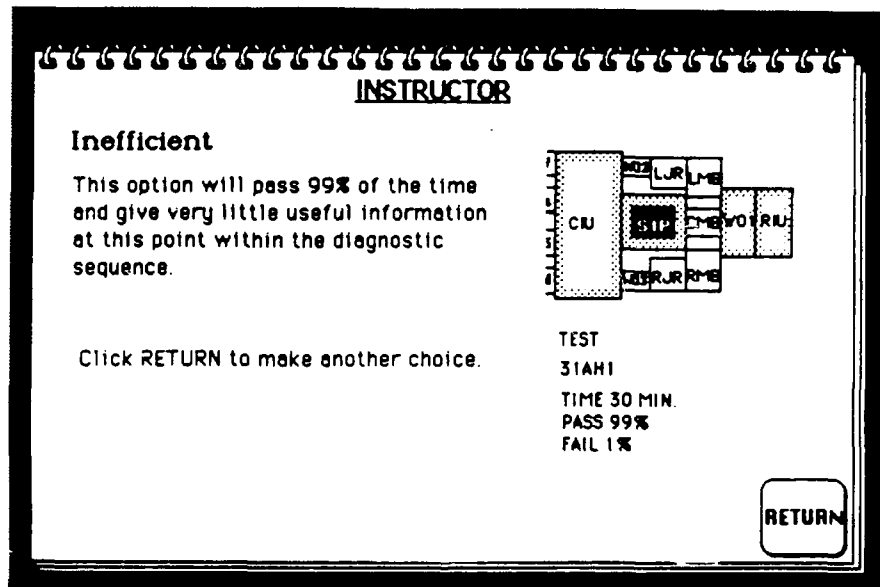


Figure 8b. Inefficient Option. This is an example of an inefficient option selection. The screen information explains why it is inefficient and contains a Return button to allow the user to return to the initial screen in order to make another selection.

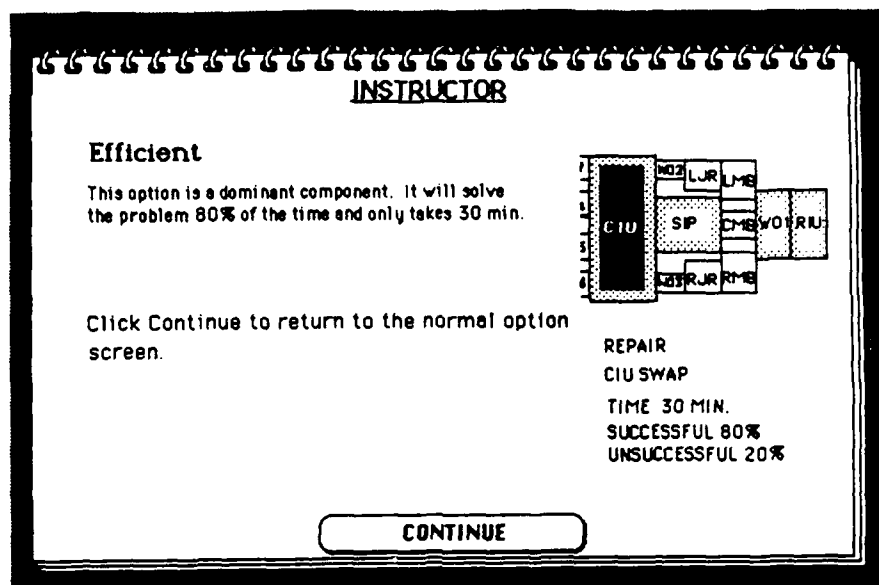


Figure 8c. Efficient Option. Selection of the most efficient option will acknowledge the proper selection and reinforce the reason as to why this selection is the most efficient. The user is then allowed to continue to the resultant plausible set.

Although the system was not formally tested, there are clear indications that a fully developed system, based upon the MDAS and training concepts applied in the demonstration system, could provide an effective tool for training technicians on systems knowledge and troubleshooting techniques. However, an actual test of the demonstration system is needed before a firm conclusion may be reached regarding its effectiveness as a training aid. Actual testing of the system will require developing a more complete training data base and providing access to a complete technical data base (or at least providing complete technical data required to support the training function). Completing the demonstration system and conducting a formal test of its effectiveness would provide critical information for development of the training function of the IMIS and should be considered.

The training demonstration system contains several features which should be considered in the development of an advanced system. The what-if module can be used by an instructor or trainer to assist in performing theoretical troubleshooting or what-if games. Current Air Training Command (ATC) course control documents call for discussion of the proper troubleshooting techniques under the instructor's guidance. To accomplish this action, the instructor would use all available aids such as technical order schematics or block diagrams. These aids are not designed as training tools to use for instruction of troubleshooting techniques; therefore, they are frequently inadequate. With the capability provided in the what-if module, the trainee is able to "see" the implications of exercising an option in either the look-ahead mode or as a selected option. Consequently, the results of both proper and improper troubleshooting techniques can be shown to the trainee and discussed.

A second use for the what-if module is that of a familiarization tool. Permitting the trainee to easily browse through all branches of the diagnostic tree will allow familiarization with the subsystem and its associated symptoms. Potential uses of this tool are in the areas of conversion training to a new weapon system, familiarization training for newly assigned 5- and 7-level personnel, and advanced preparation for pending modifications or upgrades to an existing weapon system.

The "simulation" module can be used as a stand-alone training device for training troubleshooting procedures needed to locate specific faults. The selection of a fault can be made by the computer program or it can be inserted by the instructor/trainer.

The frequent fault choice is envisioned as an aid to the inexperienced technician. It provides training in those areas that would be encountered in a day-to-day environment. The rare fault selection allows the experienced technician the opportunity to prepare for problems that are seldom seen but do occasionally occur. The random fault selection removes that information pertaining to the fault which could be gleaned by knowing how often the fault occurs. This helps prevent the inexperienced technician from developing bad troubleshooting habits. The instructor-entered selection allows the instructor to choose the faults on which the technician works. The choice can be one the trainee needs more work on, or one that simply allows the instructor to question the trainee in depth while troubleshooting.

The demonstration has shown that it is feasible to use some of the same data sources for diagnostics and training and that it is desirable to do so. However, it is clear that the data provided by the MDAS and the technical data base must be extensively supplemented to support the training function. The development of the instructor data base to provide this additional information is not a trivial matter. It must be done with the MDAS as a starting point and with clearly defined instructional objectives and techniques as a guide. The demonstration system employed very basic instructional techniques which appear to be effective. However, an effort should be made to ensure that the most effective training techniques available are incorporated into any training system developed for use with the IMIS.

The training data base problem raises an interesting issue. Should the training capability be part of an enhanced MDAS which draws from a training data base and a technical data base to provide a specialized training capability, or should it be part of a comprehensive training system which draws data from the MDAS and technical order data base to provide training in system knowledge and troubleshooting? Should the training system be an independently developed system which the IMIS simply "taps into," or should it be an integral part of IMIS? The assumption has been that there will be a separate training system which IMIS accesses. However, unless this system is designed specifically for use with the IMIS, valuable training capabilities such as those provided by MDAS may be overlooked or, at best, not fully utilized. The long-term goal of IMIS is to develop a common data base of non-redundant information to be used for technical data training and diagnostics. The relationship between the IMIS and the automated training system with which it is to work requires serious consideration early in the IMIS design process.

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The training demonstration system developed in this effort was intended as a proof-of-concept demonstrator, not a fully functional system. Although the concepts demonstrated appear to have great potential as a training aid, the system was not formally evaluated. Thus, firm conclusions cannot be drawn as to its effectiveness as a training aid. However, this demonstration effort does support the following conclusions.

1. The use of the MDAS data base and algorithms as a basis for training technicians in troubleshooting techniques and systems knowledge is feasible and desirable. The MDAS capability to readily access various types of supporting information and the what-if feature provide the basis for an effective training system.

2. The MDAS must be supplemented by an instructor data base to provide additional training materials, including information which normally would be provided by an instructor, performance evaluation materials, feedback, and exercises designed to maximize learning. The development of the instructor materials must be done with the MDAS as the baseline.

3. The development of a system similar to the demonstration system will be positively received by technicians and instructors.

Recommendations

Based upon the initial reaction from the field and above conclusions, further actions toward development of the IMIS training module should be initiated.

1. Further development of selected applications of diagnostics training, as recommended in this paper, should be accomplished. Selection should be made using the F-16A SMS data presently available in the diagnostics module to conduct a test between this module and the existing training method. This will require a coding effort that was not required in the initial demonstration. Such an effort would also foster the necessary integration of modules within IMIS and further overall IMIS planning. This would enable the training module to interact with the data bases.

2. The existing training demonstration should be presented at a technical interchange meeting with other AFHRL divisions which are also involved in research developments related to training. These divisions include the Training Systems Division (AFHRL/ID), which is working on the Advanced On-the-job Training System (AOTS) project, and the Manpower and Personnel Division (AFHRL/MO), which is working on the Basic Job Skills (BJS) project. After technical interchange and coordination, a program plan for the AFHRL/LR IMIS training module should be developed.

3. The IMIS diagnostic and training demonstration systems are visual systems which can and will stimulate the student's logic and senses. Its capability to exercise student analytical abilities and imaginative senses should be thoroughly explored since the payoffs are known to be high in this area.

The above recommendations should be quickly initiated. This rapid response will allow for the continuation of the current momentum and capture the enthusiasm expressed in the field. It will also ensure adequate inclusion of the training capability in the overall IMIS planning.

REFERENCES

- Brandt, C. M., Jernigan, J. H., & Dierker, R. J. (1987, October). Integrated Maintenance Information System: Training technology scenarios (AFHRL-TP-87-18, AD-A187 960). Wright-Patterson AFB, OH: Logistics and Human Factors Division, Air Force Human Resources Laboratory.
- Link, W. R., Von Holle, J., & Mason, D. (1987, November). Integrated Maintenance Information System (IMIS): A maintenance information delivery concept (AFHRL-TP-87-27, AD-A189 335). Wright-Patterson AFB, OH: Logistics and Human Factors Division, Air Force Human Resources Laboratory.
- MIL-STD-1553B. (1978, September 21). Aircraft internal time division command/response multiplex data bus. Washington, DC: Department of Defense.

BIBLIOGRAPHY

- Boyle E. (1989). Small unit maintenance manpower analyses (SUMMA) (AFHRL-TR-89-26). Wright-Patterson AFB, OH: Logistics and Human Factors Division, Air Force Human Resources Laboratory.
- Boyle, E., Goralski, S.J., & Meyer, M.D. (1985). The aircraft maintenance workforce now and in the twenty-first century research report. Air Force Journal of Logistics, 9(4), 3-5.
- Brown, J.S., Burton, R.R., Bell, A.G., & Bobrow, R.J. (1974, December). SOPHIE: A sophisticated instructional environment (AFHRL-TR-74-93, AD-A010 109). Lowry AFB, CO: Technical Training Division, Air Force Human Resources Laboratory.
- Cooke, G.R., Jernigan, J.H., & Treadway, J. (1986, November). Development of a Model Based Diagnostic Aiding System (MDAS). Unpublished manuscript.
- Faucheux, G.N. (1987, December 24). Training and Job Aiding for Integrated Maintenance Information System (IMIS) (Subcontract SEI-AF10-3024-02). Prepared for Systems Exploration, Incorporated by Advanced Technology, Incorporated.
- Goodman, D. (1987). The Complete Hypercard Handbook. New York: Bantam Books.
- Hollan, J.D., Hutchins, E.L., & Weitgerman, L. (1984, Summer). Steamer: An interactive inspectable simulation-based training system. The AI Magazine, pp. 15-27.
- Maze, R. (1988, April 11). 25% of reservists said inadequately trained. Air Force Times, pp. 26-27.
- McCoy, T.W. (1986, December). New ways to train. Air Force Magazine, pp. 54-61.
- U.S. Department of the Air Force. (1986). Instructional systems development (AFM 50-2). Washington, DC: Government Printing Office.
- Uttal, J. (1988, January). Teaching UNIX. UNIX World, pp. 60-65.